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INTERPRETING WILD SEEDS FROM ARCHAEOLOGICAL SITES: A DUNG CHARRING EXPERIMENT FROM THE ANDES

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ABSTRACT. — Many parts of the Andean highlands are grasslands. In these areas, the inhabitants need to use dung regularly for fuel. This fuel use is also a likely scenario for the pre-Hispanic past. Because of this, we must be careful about interpreting plant taxa that possibly could have entered the archaeological record via burned dung. To better understand the sources of small seeds in xerophytic Andean sites, we charred samples of modern dung from three regions in the Andes to assess their charred seed contents. We find that seed contents in charred dung differ by region and by animal. Our data suggest that certain co-occurring seed taxa in camelid dung may be considered a likely dung signatures of these animals.

RESUMEN. — Muchas partes de la zona alta andina son pastizales. En estas áreas, los habitantes necesitan usar regularmente estiércol como combustible. Este uso como combustible es también un escenario probable para el pasado prehispánico. Por ello, debemos tener cuidado acerca de la interpretación de taxa vegetales que posiblemente puderian haber entrado en el registro arqueológico por vía del estiércol quemado. Preocupadas acerca del origen de semillas pequeñas en sitios arqueológicos andinos en ambientes secos, llevamos a cabo un experimento quemando estiércol animal moderno para estudiar su contenido después de carbonizarlo. Hemos quemado una serie de estiércoles animales modernos de tres regiones de los Andes. Presentamos los resultados de estos experimentos quemando estiércol moderno de los Andes para evaluar su contenido de semillas carbonizadas. De las tres regiones de los Andes encontramos que los taxa vegetales difieren por región y por animal. La co-presencia de ciertos taxa es suficientemente común para los camélidos como para ser considerados probables "firmas" de estiércol, a tomarse en cuenta al hacer interpretaciones de datos.

RÉSUMÉ.— Plusieurs parties des Hautes-Terres des Andes sont constituées de prés. Dans ces zones, les habitants doivent utiliser les excréments comme combustible. Un tel usage des excréments a pu être répandu durant la période préhispanique. Ainsi, nous devons être prudents lorsque nous interprétons des taxons de plantes qui ont pu se glisser dans les données archéologiques par le biais d'excréments brûlés. Préoccupés par l'origine de petites graines provenant de sites environnementaux secs des Andes, nous avons procédé à une expérimentation en carbonisant des excréments d'animaux modernes pour connaître leur contenu après la carbonisation. Nous avons carbonisé une série d'excréments d'animaux contemporains provenant de trois régions andines. Nous présentons les résultats de ces expérimentations visant à évaluer le contenu carbonisé des graines provenant d'excréments d'animaux modernes des Andes. Nous avons découvert que les taxons de plantes diffèrent selon chacune des trois régions andines par région et par animal. Certains taxons cooccurrents se présentent assez fréquemment dans le cas des camélidés pour être traités comme des "signatures" d'excréments pouvant être prises en considération dans l'interprétation des données.

The goal of this study was to assess burnt animal dung as a source of seeds in archaeological soil flotation samples from the Andes of South America. Dung is a common constituent of flotation samples from the Andean highlands (Browman 1986:140; Hastorf 1993; Lennstrom 1991; Johannessen and Hastorf 1990; Pearsall 1983, 1988, 1989; Wright, Hastorf, and Lennstrom, in press). Dung is also a preferred fuel source for many uses today in the high, dry grassland regions of the Andes mountains (Winterhalder, Larson, and Thomas 1974). Archaeologists have found dung fragments in excavated soil flotation samples for some time and are aware of its importance as a fuel source (Browman 1986; Pearsall 1988). The extent of dung use and it's impact on the interpretation of plant assemblages from archaeological sites continues to be an issue in paleoethnobotanical interpretation. Thus, we set out to assess what seeds occur in dung, what happens taphonomically to those seeds when they are burned, and how the seeds in dung reflect the local Andean environment. We hope our data may contribute to better modeling of this aspect of past human behavior and plant use.

ETHNOGRAPHY OF DUNG USE

Today, dung from many domesticated animals, e.g., cow, sheep, goat, guinea pig, llama, and alpaca, is used as fuel, but it is particularly camelid dung that we find in the archaeological samples. We believe that domestic camelids, the llama (*Lama glama* L.) and alpaca (*L. pacos* L.) were the most important dung sources in most archaeological settings. Llamas are the more common species today, but alpacas may also provide dung. Llamas and alpacas mark their territory by defecating in mounds. Thus, their dung is easily collected from both corraled or free ranging animals. Camelid dung is large and sufficiently distinctive that fragments in floated soil samples are identifiable.

In the Andes, the traditional cooking fire is most often a small hearth, with baked earth sides, placed against a wall. Where hearths are protected from wind, they are typically above-ground and thus oxidizing in nature. Most are fueled heavily twice a day, then left to smoulder for hours. Most habitation compounds have a pile of fuel in the cooking area. Some families maintain a dung pile in their nearby corrals that is periodically treated to make it better fuel (Sikkink 1988). Dung, twigs, maize cobs, straw, and wood are used in these fires (Johannessen and Hastorf 1990:67). Next to wood, dung is the preferred traditional cooking fuel in the Jauja region of Peru (Johannessen and Hastorf 1990:68). *Watias* or field ovens in modern Bolivia and Peru use large quantities of camelid dung as fuel for roasting meat, potatoes, vegetables, and cheese. These slow and steadily burning fires remain hot for hours. As ovens may be dug slightly into the earth, they can produce more of a reducing atmosphere. Chávez (1986) and Sillar (1994) attest to the preference for camelid dung as fuel in the open-air firing of pottery, built and burned above ground.

ARCHAEOLOGICAL PATTERNS

In our work with archaeological materials from the Middle Horizon site of Tiwanaku[1] in Bolivia (ca. AD 400-1000), camelid dung remains show a distinctive depositional pattern among the excavation areas (Wright, Hastorf, and Lennstrom, in press). It would appear that in many areas, dung is being treated differently from other refuse. Not all areas within Tiwanaku display the same intensity of dung use. For example, dung is more likely than other archaeobotanical remains to occur discretely in pits rather than being distributed across floor and living surfaces. We have suggested that these patterns of dung distribution at Tiwanaku may reflect not only the inhabitants' use of dung as fuel, but also their conceptions of purity and spatial boundedness, including social and possibly ethnic or moiety differences at that capital city.

In addition to pieces of dung recovered from the flotation samples, we have also found many seeds that might have entered the record by way of dung burning. Clearly, dung was at settlements and was probably used as a fuel. What we hope to clarify here is the range of plant taxa represented by and the conditions of the seeds that might have entered the site through the use of dung as fuel. These results will inform interpretations of the archaeobotanical evidence in different Andean cultural contexts.

Seeds in Andean dung. — The vast majority of seeds recovered from samples excavated at Tiwanaku[1] are of small weedy taxa that could be from animal dung. We decided that a controlled study of the seeds in modern burned dung samples of known provenience would contribute to our understanding of the Andean archaeobotanical samples, not only from the Tiwanaku excavations, but from dry-environment archaeological sites in general. We need to better understand the sources of seeds that we find in our soil flotation samples in order to better interpret the activities they represent.

Miller (1984, 1997), Miller and Smart (1984), and Miller and Gleason (1994) have shown for Old World sites that small seeds may come from dung burned at the site. Burned dung is particularly likely to be the source of small weedy seeds of dry environments such as steppes and high mountain regions where other sorts of fuel are scarce. However, we cannot simply assume that all small seeds recovered from flotation on sites in dry environments are from dung (Hillman, Legge, and Rowley-Conway 1997). There are many paths by which seeds enter the archaeological record (Pearsall 1988).

Hastorf's Archaeobotany Laboratory — now housed at the University of California at Berkeley — over the years has received samples of modern dung from highland regions of Peru, Argentina, and Bolivia, locations where we have participated in archaeological excavations. The plant communities available to grazing animals in these areas are known, so we may determine the plant taxa actually included in the dung, and more importantly, identify the taxa which survive burning.

Such a study of plant use and seed transformation also provides a means to investigate ecological zone use archaeologically, since it is known that contemporary and prehistoric Andean plant assemblages vary quite dramatically by altitudinal zone (Pulgar Vidal 1946; Weberbauer 1945). If dung samples from different areas and various animal species produce readable "signatures" of weedy plant assemblages that reflect local plant communities, this study will provide a more concrete understanding of seed densities and taxa attributable to archaeologically burnt dung, as opposed to direct human use of the small seed taxa.

METHODS

Pre-tests. — First we designed a burning strategy to mimic the most likely types of fires lit in the past as well as the way small seeds were released from dung by burning. An initial pre-test of five camelid dung burnings was undertaken, varying the atmosphere, temperature, and length of heat treatment. In addition, one control dung sample was analyzed unburned. The oxidized samples were burned in an open environment using wood matches as tinder, as wood is easily distinguished from dung matrix and seeds under the microscope post-firing. The reducing samples were embedded in sand within a metal container and heated over a Bunsen burner until charred. Burning time was five-six minutes for the oxidizing samples and 210-240 minutes for the reducing samples. Samples were burned until they were charred throughout. The temperature of the reducing samples ranged from 200° to 600° C. The temperature of the quick-burning oxidizing samples was neither controllable nor accurately measurable. These initial burnings were completed in an attempt to determine which conditions best reproduced past dung use, especially to assess the preservation in flotation sample dung.

Total seed counts were 21.0 seeds/10 gm sample for the reducing atmosphere ($n = 2$), 20.3/10 gms for the oxidizing atmosphere ($n = 3$), and 29/10 gms in the unburned sample ($n = 1$). These figures indicate that 1/3-1/4 of the seeds are destroyed during the burning process. However, the burning did not seem to selectively destroy any particular taxon. The differences in seed counts between oxidizing and reducing conditions was not significant either. In addition, the relative proportions of the different plant taxa present after the burnings do not appear radically different, as can be seen in Figure 1. This is logical, given that the seed taxa represented are all small, compact, and dense.

Since the differences between oxidizing and reducing atmospheres were minimal, we elected to burn the rest of the samples in an oxidizing atmosphere, as this required much less burn time. It may also better represent what actually happened to most dung in past hearths when it was burned for fuel. Though some dung would have been covered by ash sufficiently to have been burned in a reducing atmosphere, most was burned with an open flame in an open hearth.

The burned samples. — From our Archaeobotany Laboratory collections, we selected 25 additional samples of dung, mostly camelid, but also guinea pig (*Cavia* cf. *porcellus*, known locally as *cuy*) and goat (*Capra* spp.) from three sampled regions:

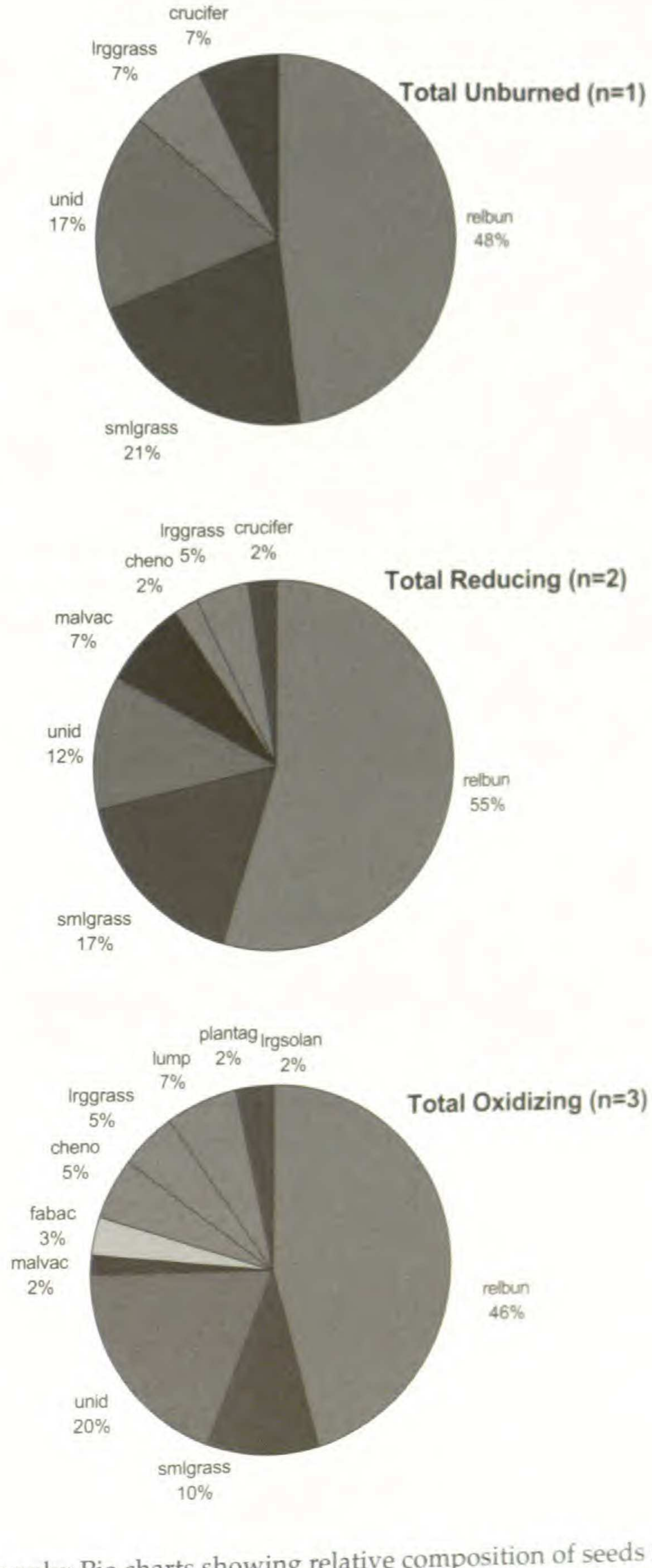


FIGURE 1.— Pre-tests only: Pie charts showing relative composition of seeds from Bolivian camelid dung samples, untreated and treated by reducing and oxidizing atmospheric burning conditions. For pie slice headings, see Appedix 1B.

TABLE 1. — Source and location of the dung samples.

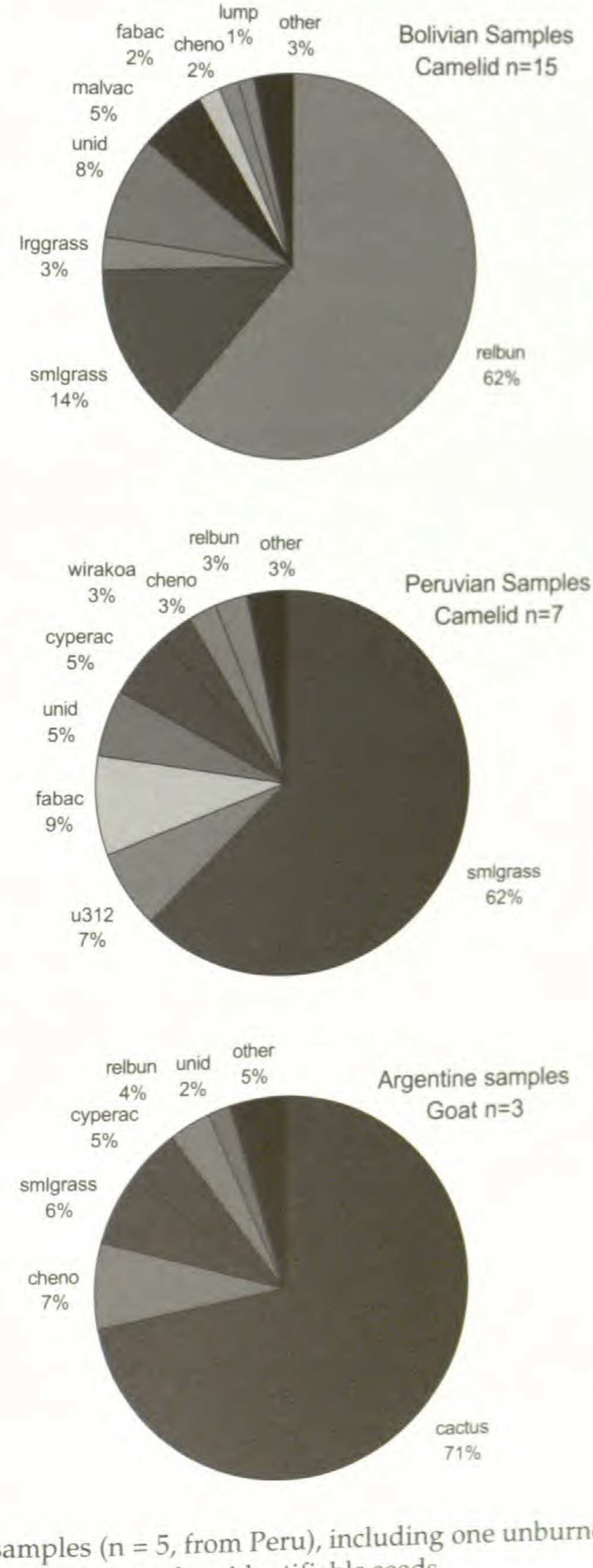
	Guinea Pig	Goat	Camelid	Total
Argentina	0	3	0	3
Peru	5	0	7	12
Bolivia	0	0	16	16
Total	5	3	23	31

Jauja in Peru, Tiwanaku in Bolivia, and Cachi in Argentina. As our dung was limited, we chose ten grams of dung for each sample. For comparison, we analyzed a further sample of unburned guinea pig dung. Along with the six test samples mentioned above, we analyzed a total of 31 ten-gram samples. The number of samples varied by animal species and by source region. These data are listed in Table 1.

Our main focus was on camelid dung from Bolivia in order to be most comparable with the local Tiwanaku samples. However, we added other animals and regions to gain as much information as possible about dung in the Andes. Half (16) of our 31 samples are from Bolivia; 23 of the 31 are from camelids. We burned and analyzed three samples of goat dung collected from the valleys near Cachi in north-west Argentina. Twelve samples of dung came from the Mantaro Valley in Peru; seven of camelid dung were collected in the nearby high puna; five samples of guinea pig dung were collected from a household on the Mantaro Valley floor; and 16 samples of camelid dung derived from the fenced enclosure surrounding the site of Tiwanaku in the altiplano of Bolivia, near Lake Titicaca, all high intermontane valley locations.

The experiment. — Each of the samples to be burned was weighed prior to and after burning. We also recorded the burn time once completed. As in the pre-test, the dung was burned on top of the ignited wood tinder for about five minutes. When there were no more open flames (although sometimes still burning embers), the burned residue was sifted through a series of geological sieves, gently shaking and prodding with probes to aid the separation. Sieves of 2 mm, 1.18 mm, and 0.5 mm were used to separate the burnt dung and extract the seeds. The seeds from this oxidizing treatment seemed to retain their shape and had minor charring contortions, which was helpful in our study. Each of these fractions was sorted under a microscope at 5x-25x. The seeds and seed fragments were then removed and identified, sometimes to genus, but usually only to family. The wood tinder remains were removed.

The counts of whole seeds and seed fragments greater than half of the seed were recorded by taxon. Figure 2 displays pie charts showing the relative proportions of the different taxa by region and animal. We undertook further statistical analyses in an attempt to identify plant taxa or combinations of taxa which might act as "signatures" for certain animals or certain environments (using SAS for Windows ver. 6.03 on a PC).



N.B. The Guinea Pig samples (n = 5, from Peru), including one unburned sample (see sample 23 in Appendix 1), contained no identifiable seeds.

FIGURE 2. — Pie charts showing relative composition of seeds from burned dung samples by region and animal; for comparison, the one unburned camelid sample is shown in Figure 1.

RESULTS

We present the results of our burning experiment in two major categories; by the animal producing the dung and by the region where the dung was collected. The complete data set is listed in Appendix 1. Both the region and the animal taxon affected the results. It is unfortunate that due to the limited samples available, we were not able to separate these two variables completely. Nevertheless, we can still draw some useful conclusions about seeds entering the archaeological record via burnt dung.

By animal. — In this larger sample, animal type (and region) did have a significant effect on what seeds are contained in the dung, unlike the pre-test when there were no major differences. We were unable to examine these differences systematically across all three animal taxa and all three zones, since all the goat dung was from Argentina and we had no camelid dung from there. Therefore it is difficult to say whether the differences observed are due to animal behavior, to location, or both (Figure 2).

One difference is clearly related to the animal species. Guinea pig dung, both charred and uncharred, contained no recognizable plant macroremains from either Bolivia or Peru. (We had no guinea pig dung from Argentina.) Apparently guinea pig digestion rarely allows for whole seed survival.

Some differences emerge from an analysis of the contents of the goat dung from Argentina and the camelid dung from Bolivia and Peru. The three goat dung samples average 5.33 plant taxa per sample (16-59 seeds/sample). The 23 camelid samples average 4.60 plant taxa/sample (4-46 total seeds/sample). Thus, goat dung was more productive of seeds than camelid dung, and the goats grazed less discriminately, as a greater range of plant taxa appeared in their dung than in that of the camelids.

If the range of plants represented in the dung seed assemblages are compared with the current local plant communities in the three regions, the difference between the two animals is noteworthy. The environment around Cachi, Argentina is a relatively sparse, high, dry desert (Heyne 1992) with perhaps fewer species available for grazers when compared to the altiplano grasslands of the Tiwanaku Valley (Weberbauer 1945; Pulgar Vidal 1946) or the Peruvian puna, which is like the altiplano, high and cool, but slightly wetter (Weberbauer 1945; Tosi 1960). Though there were fewer plant taxa available, the goats utilized a broader range of plant taxa. We may infer that goats are less discriminating grazers than camelids, or that the goats ranged across more microenvironmental zones.

The eight most commonly occurring plant taxa from all large animal dung samples taken together (in decreasing order of frequency) are 1) *Relbunium* (Rubiaceae), 2) small grasses, 3) *Chenopodium* (Chenopodiaceae), 4) Malvaceae, 5) Fabaceae (wild legumes), 6) large grasses (mainly *Stipa ichu*), 7) Cyperaceae (sedges), and 8) Cactaceae. These eight taxa were placed in a simple discriminate analysis (SAS procedure DISCRIM) to test the ability of the plant assemblages to associate with and therefore identify the animals producing the dung (Table 2). Based on this analysis, 100% of guinea pig dung samples were correctly classified, 67% of goat samples (with 33% misidentified as camelid), and 96% of camelid dung (both Bolivian and Peruvian samples). One seedless camelid sample was misclassified as guinea pig.

TABLE 2. — Discriminant analysis by animal taxa.

ANIMAL	Guinea Pig	Goat	Camelid	Total
Guinea Pig	5	0	0	5
	100.00	0.00	0.00	100.00
Goat	0	2	1	3
	0.00	**66.67**	33.33	100.00
Camelid	1	0	22	23
	4.35	0.00	**95.65**	100.00
Total	6	2	23	31
	19.35	6.45	74.19	100.00
Priors	0.1613	0.0968	0.7419	

These clusters suggest that the seed taxa should allow us to identify correctly the animal that produced the dung in these different environments. These results also have interesting implications for analyzing Colonial assemblages, where sheep, goat, or cattle dung may have been used as fuel in addition to camelid dung. If these dung occurred on a site, we might be able to model their entrance into the deposits and therefore the extent of their use. Archaeologically, however, the only two fuel dung sources were camelid and guinea pig, and our results make clear that any identifiable macrobotanical remains from dung would be from camelids. For the altiplano therefore, we are only concerned with the seeds that entered the pre-contact archaeological record via camelid dung use.

By region. — The differences in the plant taxa found in the dung are most striking when regions are compared. The three sources of dung — Bolivia, Peru, and Argentina — occur in quite distinct proportions (Figure 2). The Argentine goat samples (n = 3) are overwhelmingly Cactaceae, with some *Chenopodium* and grasses. The Peruvian camelid assemblages (n = 7) are dominated by grasses, with significant amounts of wild legumes and sedges, and some *Chenopodium*. (The five guinea pig samples from Peru contained no identifiable seeds.) The fifteen Bolivian camelid samples, are dominated by *Relbunium*, with grass as the next most common plant category, along with some Malvaceae, *Chenopodium*, and Fabaceae (wild legumes).

We conducted discriminate analysis using the same technique as above but with the dung samples grouped by region rather than by animal. We again used the eight most common plant taxa, in order to see how accurately one could identify the region from which the dung came from the plant assemblages present in the dung (Table 3). The region was correctly classified in 67% of the Argentine samples, 88% of the Peruvian camelid samples, and 94% of the Bolivian samples.

In an attempt to refine the discriminating power still more, the four most common taxa from each location were combined to create new discriminating variables: FACTARG, FACTPERU, and FACTBOL. FACTARG includes Cactaceae + *Chenopodium* + small Poaceae + Cyperaceae, FACTPERU has small Poaceae + Fabaceae (wild legume) + Unknown 312 + Cyperaceae, and FACTBOL includes *Relbunium* + small Poaceae + Malvaceae + large Poaceae. Using only these three variables, correct classification increased to 100% for Argentina, 88% for Peru, and 94% for Bolivia (Table 4). Thus it would appear that we have fairly good regional "signature" plants within the dung seeds we analyzed.

TABLE 3. — Discriminant analysis by region.

SITE	Argentina (goat)	Peru (camelid)	Peru (guinea pig)	Bolivia (camelid)	Total
Argentina (goat)	2	0	1	0	3
	66.67	0.00	33.33	0.00	100.00
Peru (camelid)	0	7	1	0	8
	0.00	**87.50**	12.50	0.00	100.00
Peru (guinea pig)	0	0	4	0	4
	0.00	0.00	**100.00**	0.00	100.00
Bolivia (camelid)	0	0	1	15	16
	0.00	0.00	6.25	**93.75**	100.00
Total	2	7	7	15	31
	6.45	22.58	22.58	48.39	100.00
Priors	0.0968	0.2581	0.1290	0.5161	

TABLE 4. — Discriminant analysis by region, using regional factor variables, defined by the four most common taxa within the dung.

SITE	Argentina (goat)	Peru (camelid)	Peru (guinea pig)	Bolivia (camelid)	Total
Argentina (goat)	3	0	0	0	3
	100.00	0.00	0.00	0.00	100.00
Peru (camelid)	0	7	1	0	8
	0.00	**87.50**	12.50	0.00	100.00
Peru (guinea pig)	0	0	4	0	4
	0.00	0.00	**100.00**	0.00	100.00
Bolivia (camelid)	0	1	0	15	16
	0.00	6.25	0.00	**93.75**	100.00
Total	3	8	5	15	31
	9.68	25.81	16.13	48.39	100.00
Priors	0.0968	0.2581	0.1290	0.5161	

It is a worthwhile exercise to compare the plant assemblages in dung from the different regions with contemporary regional plant communities. The Peruvian and Argentine dung assemblages correlate fairly well with the known modern plant communities. The dry landscape around Cachi, Argentina, is dominated by cacti and leguminous trees, as is the archaeological wood assemblage (Heyne 1992). The Peruvian camelid samples were collected in the high moist puna, an area dominated by grasses (Weberbauer 1945; Pulgar Vidal 1946). The presence of sedge suggests that camelids do occasionally feed in areas near streams and springs within their grazing ranges, a preferred habitat for sedges. In fact, camelids do like moist areas.

The Bolivian plant community is somewhat anomalous when compared to the plant taxa represented in our sample dung from that region. We would not have predicted the high percentage of *Relbunium* found in the dung given the living plant community in that part of the Tiwanaku Valley. The camelids from which the dung was collected graze primarily in the enclosed precinct of the archaeological site of Tiwanaku. The seven most common plant taxa, after *Relbunium*, in the 16 Bolivian camelid dung samples that we studied, are (in order of abundance): small Poaceae, Malvaceae, large Poaceae, Fabaceae (wild legume), *Chenopodium*, Cruciferae, and Plantaginaceae. However, a botanical reconnaissance of the area did not reveal significant concentrations of *Relbunium*. Instead, this zone is dominated by *ichu* grass (*Stipa* sp.), *t'ola (Baccharis microphill*, Asteraceae), and *khoa* (*Mentha puleguir* and *Satureja boliviana*, Lamiaceae), with a lesser number of leguminous creepers (*Astragalus)*, Asteraceae, and other grasses (Hastorf, Lennstrom, and Wright, field notes). This contrast suggests that the camelids are feeding preferentially on *Relbunium*. If this is so, *Relbunium* present in carbonized archaeological assemblages from the altiplano, or at least in the Tiwanaku Valley sites, may serve as a "signature" of burnt camelid dung. However, some *Relbunium* spp. were used in the pre-Inka Andes as source of a red dye, so there could be other explanations for the presence of this taxon in a site.

Pearsall (1988:103) identified seeds from three modern camelid dung samples from the Junín puna, a high, wet plain like the puna from which we collected the Peruvian camelid dung. She found the following taxa in those samples: Cyperaceae, Caryophyllaceae, *Opuntia floccosa* (Cactaceae), *Sisyrinchium* (Iridaceae), *Relbunium*, *Calandrinia* (Portulacaceae), *Lupinus* (Fabaceae), and Poaceae of various sizes. Several of these taxa also occur in our modern Bolivian and Peruvian camelid dung samples, listed above. Flannery had Pickersgill look at the llama food preferences in Ayacucho as part of his herding study (Flannery, Marcus, and Reynolds 1989:49). There, the camelids preferred grasses, Malvaceae, cf. *Lycopodium* (Lycopodiaceae), a wild legume (*Astragalus)*, lichens, and several Asteraceae. This was a broad diet. Range management studies at the field station, La Raya, Peru, have tracked alpaca food preferences as they ranged freely (Bryant and Farfan 1984). These alter with the season of the year, but in general alpacas too consume a broad diet. While we have learned that large camelids can eat many things, if left alone to forage, they prefer grasses, Cyperaceae, with some *Plantago* (Plantaginaceae), and wild legumes (Bryant and Farfan 1984:333). Of course, the camelids could have been fed by their caretakers, which might affect the plant remain frequencies. The similarities among these analyses suggest that *Relbunium*, wild grasses, and wild legumes are common and preferred camelid foods in high elevation grasslands. Our data and Pearsall's indicate a special place for *Relbunium* in the camelid diet. *Relbunium* occurred in two of Pearsall's three samples, in three of our seven Peruvian puna samples, and in all 16 of our samples from Bolivia.

IMPLICATIONS FOR ARCHAEOLOGICAL INTERPRETATION

The dung samples from the various regions are not strictly comparable. To facilitate conclusions about dung as a source of archaeological seeds, it is advisable to collect data from a specific study region and its associated environmental zones. It would be worthwhile to examine the distribution of the "signature" taxa such as *Relbunium* and the wild grasses, such as *Calamagrostis* and *Poa*, in conjunction with dung fragments at sites such as Tiwanaku or Chiripa. For starters, one may note patterns in the distribution of these taxa in identifiable dung fragments found in soil flotation samples. If the frequencies of seeds normally occurring in dung are different than in the dung fragments, we may better understand the effects of dung fragmentation. One could also construct a "weighting" or "marking" variable for the regularly occurring dung seed taxa and apply it to interpret contexts where that combination of seed taxa occurs. Some excavation locations would have both dung fragments and these dung seed taxa, but some may have only the seeds. In either case, we could use such "marking" to characterize more sensitively the distribution of dung at sites, and to gain hints about the processes by which the fragments have broken down. In this way we may be better able to infer the presence of camelid dung as well as gain information about the levels of trampling and destruction that may have occurred in different locations on a site.

CONCLUSIONS

This modest experimental study demonstrates that camelid dung burned as fuel is a likely source of seeds in Bolivian archaeological flotation samples. Dung seed content appears not to differ significantly in different burning atmospheres. Thus, a wide variety of burning conditions could have left dung seeds at sites, although there will be some taphonomic seed loss from burning. Seed taxa in dung differ depending on the animal species from which the dung is derived, the season of the year, and the region. In particular, guinea pigs tend not to eat seeds, while goats and Andean camelids do. The selectivity of the grazer may play a role in the diversity of seeds present in the burnt dung, and certain plant taxa may be preferred by certain animals. This grazing selectivity may allow us to recognize "signatures" of dung present at specific sites.

By far the most significant differences in seed taxa seem to be due to geographical (environmental) location. The seed-from-dung assemblages for the three areas are statistically different. Although the plant taxa present are largely the same (with some notable exceptions), their proportions vary significantly. An analysis of the relative proportions of assemblages of "likely dung seeds" can also yield information about what parts of the landscape are being most strongly utilized by camelids. For example, *Relbunium* and grasses found in modern Tiwanaku camelid dung reflect a pampa grassland diet. They do not suggest that these animals had access to wetlands, as did their Peruvian congeners.

However, there are some notable problems to this approach. First, the source of "likely dung seeds" cannot be unequivocally assigned to the burning of dung. Grasses, sedges, and other small weedy taxa may have been used as construction materials, in wool dyeing, or directly as fuel, or they may have been by-products of other activities such as pottery manufacture, winnowing, or sieving of crops, as well as entering the archaeological assemblage through natural processes (Pearsall 1988). The results of our experiments show that dung regularly contains seeds and that if dung was being used regularly as a fuel (as is attested by the presence of burnt fragments of dung), many of the "likely dung seed" taxa probably came from dung.

A second problem is that seeds present in dung do not necessarily reflect the plant taxa present in the landscape in which the animals were feeding; as the animals may feed preferentially from the universe of plants available. The Bolivian samples have a preponderance of *Relbunium*, a plant which is not as common in the landscape as its proportion in the dung would suggest. However, the remaining seed taxa do reflect the grassland habitats in which the animals like to feed. The presence of certain species may also represent the season during which the dung was deposited. Provisioning animals with fodder, such as we see today with animals given totora reeds (*Scirpus* sp., Cyperaceae), could skew the interpretation of the ecological zones the camelids were using.

This study of seeds obtained from dung samples and the models we have constructed of how those seeds might enter the archaeological record represent an important step in learning to deal with those small, dense, weedy seeds that make up the majority of archaeological flotation samples in the south central Andes, as in other xerophytic places of the world. The patterns of seeds we have identified may contribute to the analysis of past landscape use, foddering activities, camelid husbandry, as well as dung use at archaeological sites.

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NOTES

[1]Work at Tiwanaku was undertaken under the auspices of Proyecto Wila Jawira, co-directed by Prof. Alan Kolata of the University of Chicago and Oswaldo Rivera S of the Instituto Nacional de Arqueología de Bolívia. Systematic soil samples of 6-8 liters were taken from every level and every feature during the excavations in 1989, 1990, and 1991. These were processed with a mechanized flotation machine (modified after Watson 1976), and the light and heavy fractions were sorted and botanical remains greater than 0.5 mm extracted and where possible identified, to family if not to genus. All flotation and analysis procedures are described in greater detail in Wright et al, in press.

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APPENDIX 1A. — Raw data.

no.	taxa	region	wt (gm)	time (min)	atmos	relbun	smlgrass	cactus	unid	malvac	fabac	cheno	lrggrass	cyperac	u312
1	camelid	Bolivia	10	5	O	1			5		1				
2	camelid	Bolivia	10	6	O	10	4			1		3			
3	camelid	Bolivia	10	240	R	15	4		5	3			2		
4	camelid	Bolivia	10	5	O	17	2		7		1		3		
5	camelid	Bolivia	10	210	R	8	3					1			
6	camelid	Bolivia	10	0	U	14	6		5				2		
7	camelid	Bolivia	10.7	4	O	26	6		3	2	2		2		
8	camelid	Bolivia	10.2	5	O	19	5		7	3					
9	camelid	Bolivia	9.8	6	O	20	3				1		1		
10	camelid	Bolivia	10.3	6	O	27	4						2		
11	camelid	Bolivia	10.2	5	O	14	4		1	1					
12	camelid	Peru	10.1	6	O		8		2		1	1	1		
13	camelid	Peru	9.9	5	O	1	20		1		3				2
14	camelid	Peru	10.1	5	O	1	11		1		1	1		1	2
15	camelid	Peru	10.1	5	O		5		2		1	1			3
16	camelid	Peru	10	5	O	2	10		1		4			5	3
17	camelid	Peru	10	5	O		37		1		1	1		2	
18	camelid	Peru	10	4	O		2				2				
19	guinea pig	Peru	10	6	O										
20	guinea pig	Peru	10	4	O										
21	guinea pig	Peru	10	140	R										
22	guinea pig	Peru	10	5	O										
23	guinea pig	Peru	10	0	U										
24	goat	Argentina	10.1	6	O	2	3	7				1			
25	goat	Argentina	10	6	O	2	2	23				3		1	
26	goat	Argentina	10	5	O		1	47	2			4		4	
27	camelid	Bolivia	10	5	O	9	2			1					
28	camelid	Bolivia	9.9	5	O	14	2		1	4	1				
29	camelid	Bolivia	10	5	O	18	4			1	1		1		
30	camelid	Bolivia	10	4	O	32				5	1				
31	camelid	Bolivia	10.2	4	O	2	5					3			

APPENDIX 1B. — *Raw Data.*

no.	taxa	region	lump	plantago	u270	wirakoa	crucifer	medgrass	lrgsolan	borage	u280	smlsolan	pick (gm)	remain (gm)
1	camelid	Bolivia	3										0.04	
2	camelid	Bolivia	1						1				0.07	
3	camelid	Bolivia											0.05	
4	camelid	Bolivia		1									0.04	
5	camelid	Bolivia					1						0.03	
6	camelid	Bolivia					2						0.07	10
7	camelid	Bolivia	1	1						1			0.13	
8	camelid	Bolivia	1									1	0.05	4.9
9	camelid	Bolivia						2					0.03	4.47
10	camelid	Bolivia											0.03	4.85
11	camelid	Bolivia			1								0.05	4.99
12	camelid	Peru											0.05	2.6
13	camelid	Peru		1				1					0.05	3.19
14	camelid	Peru			1								0.09	2.88
15	camelid	Peru		1									0.04	2.75
16	camelid	Peru											0.03	2.9
17	camelid	Peru				4							0.06	1.59
18	camelid	Peru											0.01	3.59
19	guinea pig	Peru											0	2.63
20	guinea pig	Peru											0	2.06
21	guinea pig	Peru											0	5.01
22	guinea pig	Peru											0	2.04
23	guinea pig	Peru											0	10
24	goat	Argentina			2						1		0.02	2.11
25	goat	Argentina								1			0.06	2.4
26	goat	Argentina									1		0.04	2.3
27	camelid	Bolivia							1				0.01	4.3
28	camelid	Bolivia											0.02	3.58
29	camelid	Bolivia		1									0.04	4.14
30	camelid	Bolivia											0.03	6.57
31	camelid	Bolivia											0.01	3.08

Key to Appendix 1: no = sample number of the dung sample; atmos = burning atmosphere, O= oxidizing, R= reducing, U= unburnt; relbun = *Relbunium*; smlgrass = small Poaceae; cactus = Cactaceae; unid = unidentifiable seed; malvac = Malvaceae; fabac = Fabaceae (wild legume); cheno = *Chenopodium* spp.; lrggrass = large Poaceae; cyperac = Cyperaceae (sedge); u312 = unknown seed, type #312; lump = lump of burned non-woody paraenchymous material; plantago = Plantaginaceae; u270 = unknown seed, type # 270; wirakoa = as yet unidentified plant used by the Bolivian Aymara as incense; crucifer = Cruciferae; medgrass = medium Poaceae; lrgsolan = large Solanaceae; borage = Boraginaceae; u280 = unknown seed, type # 280; smlsolan = small Solanaceae; pick (gm) = weight of the separated seeds in grams; remain (gm) = weight of the remains once the seeds had been picked out in grams.